PHYSICAL PROPERTIES OF METALS[1]

ONE of the most characteristic properties of metals is the power possessed by them when in more or less compact masses of acquiring (by polishing, pressure, or other mechanical treatment) such a condition of surface that light incident thereon is for the most part again reflected, whereby a peculiar glistening appearance is presented, known as the *metallic lustre*.

Owing to the influence of the air, moisture, vapours arising from putrefaction, &c., metallic surfaces, even when highly polished and brilliant, become more or less rapidly tarnished, so that the power of reflecting light is to a considerable extent lost. Before the invention of glass polished metallic surfaces were employed as *mirrors;* and for reflecting telescopes such surfaces are still in use. Now, however, it is usual to employ as mirrors glass surfaces behind which a thin coating of some lustrous metallic mass is placed, so that the smooth surface of the glass at once determines the peculiar reflective power of the metal applied to it, and preserves the metal from mechanical injury and from the corrosion of the air. For this reason these household appliances are ordinarily termed "looking-glasses," although strictly speaking it is not the glass that is the essential part.

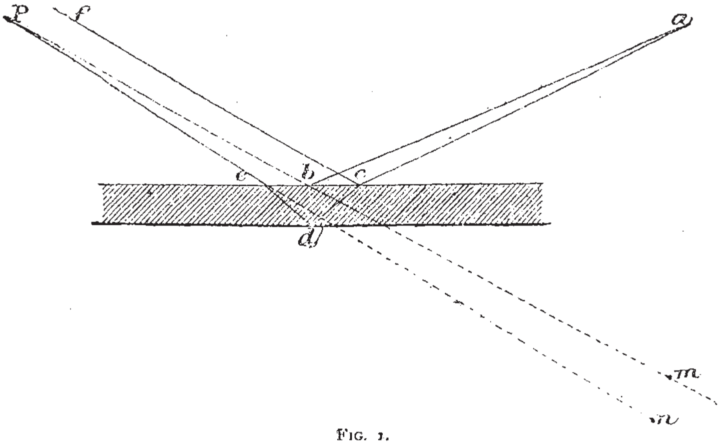

FIG. 1.

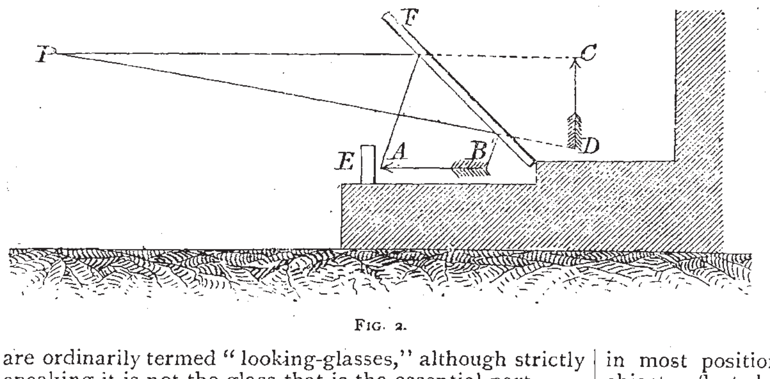

FIG. 2.

Three principal methods of applying these metallic substances to glass are in use; the best plate-glass mirrors (perfectly plain surfaces) are prepared by spreading out on a table surrounded with a deep groove or gutter, and capable of being raised on hinges so as to be placed at any angle with the horizon, a sheet of tinfoil, and smoothing it with a soft brush; mercury is then poured on and gently rubbed over the tinfoil with a hare's foot or a roll of flannel so as to penetrate and brighten the tin; more mercury is then poured on, and the surface cleansed from dross, &c.; finally, the perfectly clean sheet of glass is dexterously slid over the brilliant mercurial surface in such a way as to avoid inclosing any particles of dust or air-bubbles between the metal and glass. The table is then slightly raised at one end, so that the surplus mercury may gradually run off and be caught in the gutter; and the slope is increased daily, a piece of flannel being placed on the glass with weights on it to facilitate the draining off of the mercury. After two to four weeks, according to the size of the plate, the mirror is complete, the tin amalgam having then completely set, and being tolerably firmly adherent to the glass, although easily rubbed off and scratched on account of its slight tenacity. To preserve the back of the mirror from injury a suitable wooden frame is provided, in which the whole is fixed, when a finished mirror is the result.

For curved surfaces, such as the insides of globes, flasks, &c., for ornamental purposes, a somewhat different plan is employed: a fluid or semi-fluid amalgam capable of adhering to glass is poured into the vessel to be "silvered," and shaken about therein until the inner surface is covered with a film of the composition; the surplus amalgam is then poured out and used for other similar objects. A mixture of one part each of lead, tin, and bismuth, with two parts of mercury, answers well, the mixture being made perfectly fluid by slightly warming it before pouring into the vessel to be silvered.

A method which has of late years come largely into use for silvering mirrors of various kinds, and notably the reflectors of telescopes and lighthouses, is based on the power of certain chemical reagents to throw down silver in the metallic state from certain of its solutions, &c., the reduced silver in many cases adhering firmly to the surface of the vessel in which the action takes place, or to objects immersed in the liquid. Thus, if calcium tartrate in a moist state be placed in a glass vessel with a crystal of silver nitrate and a drop of ammonia solution, and the mixture cautiously heated, and made to flow successively over the whole inner surface of the glass, a fine mirror may be developed. Aldehyde, oil of cloves, and other essential oils, grape-sugar, and some other organic substances, may also be employed as reducing agents, especially the first substance.

If a "mirror" (*i.e.*, a glass surface with a brilliant metallic film behind) be carefully examined, it will be found that in most positions it will give a double image of any object reflected, one image being usually more brilliant than the other. Fig. 1 illustrates how this is brought about; a ray of light from an object at *a*, strikes the glass surface at *b*, and is reflected to the eye of the observer at P, so that an image is seen situated at *m*. Another ray of light incident on the glass at a point *c*, is partly reflected along *cf*, this portion of the ray consequently never reaching the eye at P at all; the rest of the ray enters the glass, being refracted along *cd*; at the junction of the glass and metallic surfaces reflection takes place along *de*, and at *e* the ray is refracted along *e* P, thus also reaching the eye of the observer, but

[1] From a forthcoming volume of the NATURE Series—"Metals and their Chief Industrial Applications. Being, with some Considerable Additions, the Substance of a Course of Lectures Delivered at the Royal Institution of Great Britain in 1877." By Charles R. Alder Wright, D.Sc., &c., Lecturer on Chemistry in St. Mary's Hospital Medical School. (London: Macmillan and Co., 1878.)

necessarily causing the image formed to be seen apparently situated at *n*, a point different from *m*. The relative quantities of light passing along *e* P and *b* P (that is, the relative brightnesses of the two images) depend on the degree of obliquity of the incident light *c*; the greater the angle *a b* P (*i.e.*, the more obliquely the light falls on the mirror), the brighter is the image at *n*. The power of glass thus to reflect light to a considerable extent without any metallic film behind is utilised in the illusion known popularly as "Pepper's ghost," which consists simply of a large pane of glass sloping forwards from the stage at an angle of about 45° (Fig. 2). Objects such as A B, placed between the footlights E, and the pane of glass F in a horizontal position, and strongly illuminated, will produce to a spectator in front at P, a virtual image or "ghost," apparently situated at C D, the illusion being heightened by hiding, by means of screens, all the apparatus in front of the pane from the audience, and darkening that part of the stage behind the pane, the real objects furnishing the ghosts being placed on a dead black ground. When the lights E are extinguished, and other lights illuminating the stage behind the pane turned on, the ghosts disappear, whilst the real actors at D C on the stage behind the pane become visible *through* the transparent glass.

Most of the metals used in the arts in the free state are of considerable density, aluminium being by far the lightest, a circumstance which, together with its considerable strength and power of resisting the tarnishing effects of the air, renders it peculiarly suitable for numerous purposes: the draw-tubes of telescopes, opera-glasses, &c., and the graduated circles of surveying-instruments, &c., are often made of this metal for these reasons. According to the way in which a piece of metal has been obtained, its density will vary somewhat, being increased by hammering or any mechanical action which forces the particles together, *e.g.*, wire-drawing or sheet-rolling. The following table gives the numerical values of the average densities of most of the more important metals :—

Specific Gravity of Metals (*Water* = 1).

Platinum	21·5	Iron	7·8
Gold	19·3	Tin	7·3
Mercury	13·6	Zinc	7·1
Palladium	11·8	Antimony	6·7
Lead	11·3	Arsenic	5·6
Silver	10·6	Aluminium	2·6
Bismuth	9·8	Magnesium	1·8
Copper	8·9	Sodium	0·97
Nickel	8·8	Potassium	0·86
Cadmium	8·7	Lithium	0·59

Although the property of being drawn into wire is closely allied to that of being rolled or hammered into foil and leaves, yet the two are not necessarily possessed to equal extents by the same metal; gold, silver, and platinum are pre-eminently "ductile," whilst copper and iron are but little inferior to them in this respect. Aluminium and zinc can be obtained in tolerably thin wire, whilst lead and tin have so little cohesion that they cannot be drawn beyond a very limited degree of fineness. On the small scale, wires are readily obtained by casting the metals into thin pencils,[1] slightly pointing the ends of these and passing them into a funnel-shaped hole in a steel plate (*draw-plate*) of suitable size, gripping with pliers the protruding pointed part, and forcibly pulling the whole bar through the hole, the process being then repeated with a slightly smaller hole.

In drawing wire on a manufacturing scale, the process is just the same in principle, only, instead of drawing the wire through the draw-plate by hand by means of a wheel and axle, &c., the wire is pulled through by hand with pliers for a foot or two, and this portion then fastened to a revolving drum which then pulls the rest of the wire through, coiling up the drawn-out portion on the drum; the wire is then passed through the next smaller hole, being uncoiled from the first drum, and coiled again on a second in so doing, and so on until drawn to the required degree of fineness. In this way great lengths of wire are drawn at one operation.

By forming metals into wires of equal dimensions, and then determining the weight requisite to break these wires, the differences in tenacity exhibited by metals and alloys may be readily demonstrated. A convenient apparatus for this purpose is made of an iron tripod six or seven feet high, the legs of which are stayed together at the bottom and in the middle; from the top of the tripod is suspended by a stout hook a dynamometer or spring balance furnished with a hook at the bottom, whilst about half way up the tripod is affixed a horizontal axle, supported by the stays in such a position that the centre of the axle is perpendicularly beneath the hook of the dynamometer. This axle is provided with a winch, and round it is coiled a stout rope or leather band with a hook at the end. The wire to be tested is formed into a ring about three or four inches in diameter, the ends being intertwisted and soldered together; the hooks attached to the bottom of the dynamometer and to the rope are then inserted in this ring, and the handle turned so as to wind up the rope and stretch the ring until its form becomes a

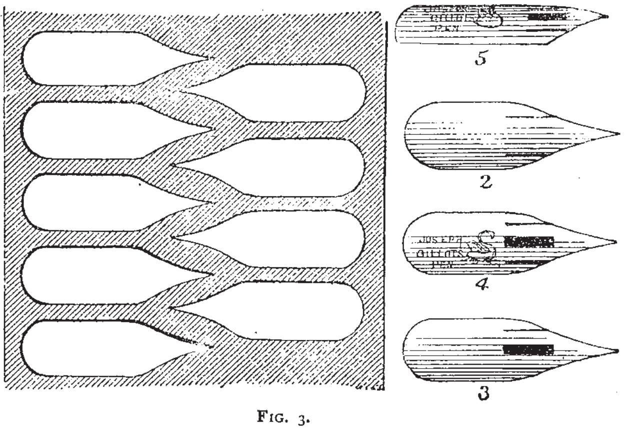

FIG. 3.

narrow oblong. The tension is then increased by winding the rope until the wire breaks; the reading of the dynamometer is noted by an assistant at the moment of rupture.

In this kind of way the order of tenacity of the metals is found to be as follows :

25 Iron.	8 Gold.
16 Copper.	7 Zinc.
14 Platinum.	1·5 Tin.
12 Aluminium.	1 Lead.
10 Silver.	

Closely connected with the physical structure which enables metals to exhibit the phenomena of crystallisation, malleability, and ductility, is the power which some possess of returning to their original shape when deflected therefrom by some external force not too great (*elasticity*); a property possessed to an extreme degree by good steel. The operations of wire-drawing, rolling, hammering, and the like generally increase the elasticity of metals, whilst annealing and fusing usually diminish it. Some metals are almost wholly devoid of elasticity; thus lead scarcely exhibits a trace of this property, being so soft that it is readily abraded by the nail. Some metals and alloys, when worked into appropriate shapes and struck, continue vibrating for some time, and hence are powerfully

[1] For metals of moderately-low melting-points the fused substance may be drawn up into a hot thin glass tube or pipe-stem by suction, and allowed to solidify therein. By fusing the metal in the bowl of a tobacco-pipe and tilting this so that the stem is inclined downwards, the molten metal can often be made to form a rough wire or thin rod in the stem readily obtainable by breaking away the pipeclay after cooling.

sonorous (*e.g.*, aluminium, bell metal, steel, standard gold, &c.).

The chief value of many metals and alloys for industrial purposes lies in their possession to a greater or less

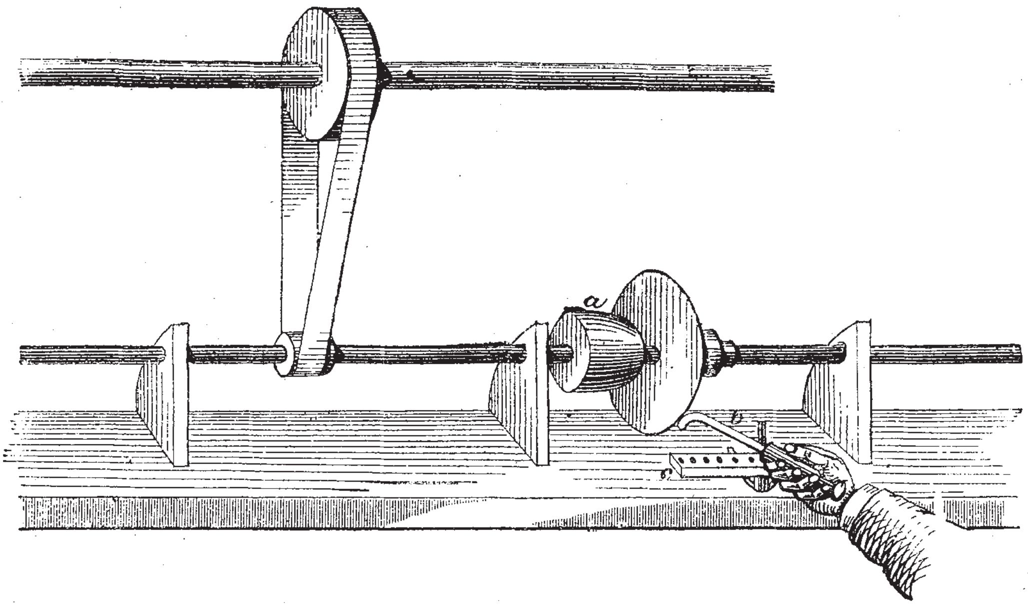

FIG. 4.

extent of a combination of properties of somewhat opposite kinds; whilst they possess sufficient rigidity to keep their shape even with moderately hard usage and to bear "wear and tear," when once fashioned into articles of domestic and everyday use, they have the power of yielding to pressure, &c., to a sufficient extent to enable them to be readily worked into these forms. In some cases the requisite softness for this latter purpose is hardly attained until the temperature is considerably raised; thus most articles of wrought iron are made when the metal is softened by heat so as to yield readily to percussion (*forging*) and other shaping processes. Closely connected with this softening or incipient conversion into a pliable mass by heat, is the phenomenon of *welding*, or

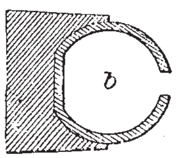

FIG. 5.

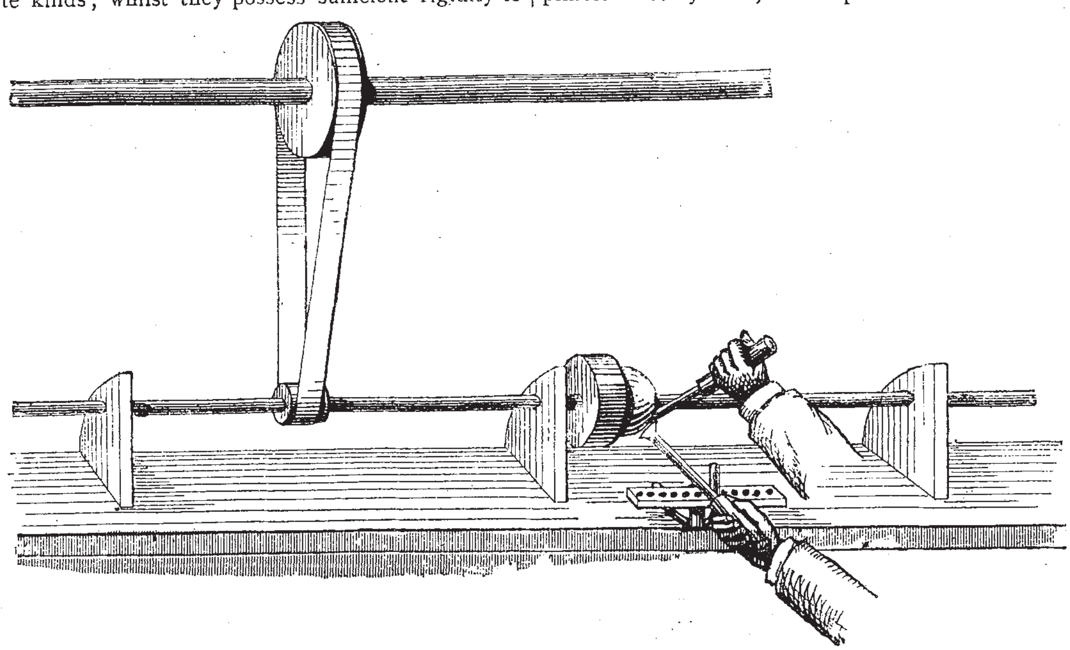

FIG. 6.

the adherence together of two separate metallic masses when united by pressure in such a way as to form a join as strong as the other parts. Iron and platinum possess this power at a high temperature; sodium and some of

the rarer metals at the ordinary temperature; gold also can be welded cold, under certain conditions, as in gold-beating. On the possession of these properties depend most of the metal-fashioning crafts, those where the metals are fused and cast being the main exceptions.

Thus in the manufacture of steel pens, as carried out by Messrs. Gillott and Sons, there are no less than eighteen stages between the conditions of bar steel and finished pen; and most of the stages are different applications of these properties of metals in reference to the shaping of the material into the required form. The bar steel is first converted into thin sheets, which are again rolled to the requisite degree of thinness; from the rolled steel "blanks" are punched out by a machine, leaving a kind of skeleton or network of "scrap steel" (Fig. 3), which is melted up or welded together and used over again. Two "side slits" are then made in the blank (No. 2), and a somewhat wider centre slit (No. 3) pierced, a portion of metal being punched out in making this orifice; the metal is then annealed and marked with the maker's name; a device or trade mark is raised by embossing (No. 4), and then the hitherto flat pen is converted into a portion of a cylinder, or curved (techically, "raised") by a suitable machine (No. 5); after which it is hardened, tempered, and cleaned by scouring with emery, &c.; the tip is then "straight-ground," *i.e.* the metal is thinned at the writing end by grinding in the direction of the length of the pen, after which it is "cross-ground," in the transverse direction. Finally the slit from the nib to the punched-out central part is cut, and the pen is coloured and varnished for sale.

Again, the manufacture of table-spoons and forks, many kinds of brass-work, cutlery, percussion-caps, copper pans and kettles, medals, and coins, and a thousand-and-one articles of every-day use, all depend upon the possibility of forcing the metal into various shapes without fracturing it, by mechanical processes, such as forging, punching, pressing, embossing, and the like. One of the prettiest illustrations of the application of pressing and shaping force is afforded by the processes in use for "teapot spinning," *i.e.* the production of a Britannia-metal teapot by a process technically termed *spinning*. The alloy being rolled into sheets of convenient thickness, a circular disc is cut out and placed in a kind of lathe as represented in Fig. 4, the metal disc being pressed against a nearly hemispherical wooden chuck *a*. The lathe being set in motion, the workman presses against the off-side of the disc with a peculiarly shaped tool, *b*, held steadily by means of the rest, *c*, so as gradually to bend the disc over the mould, *a*, and so to convert the disc into a bowl. The bowl thus formed is taken off the lathe and set with the convex part fixed into the concavity of a hollowed-out chuck (shown in section *a*, Fig. 5); by the aid of two differently shaped tools held one in each hand and applied, the one within and the other without the rim of the bowl, the metal is gradually bent inwards as it revolves, so as finally to take an almost globular shape: Fig. 6 indicates the closing stage of this operation, the nearly globular bowl thus formed being shown in section in Fig. 5 *b*. Finally the lid, spout, handle, &c., are attached, and the whole brightened and polished for the market. During the spinning the edge of the disc, some forty or fifty inches in circumference, becomes diminished to almost half that in the bowl, and to about one-quarter in the globular pot, the metal being thus as it were pressed in upon itself, as well as somewhat extended, the superficial area of the outside of the globular pot being somewhat greater than that of one side of the circular disc used in the first instance. In a similar fashion jugs and analagous vessels are "spun up," out of plates, the lips for pouring being subsequently shaped by carefully hammering or pressing out the metal on a wooden or metal mould. Silver articles, *e.g.*, bowls, teapots, &c., are frequently curved by an analogous operation; the second stage, however, cannot so well be applied to silver, so that if a closed-in vessel is required like a teapot, it is usually made in two halves, neatly soldered together.

SCIENTIFIC RESULTS OF D'ALBERTIS' LAST EXPEDITION TO NEW GUINEA

NOT long ago (NATURE, vol. xvii. p. 383) we gave a short narrative of M. D'Albertis' recent expedition to New Guinea. Through the kindness of Dr. George Bennett, of Sydney, New South Wales (at present in London) we are now able to add the following extracts from a letter just received from that distinguished explorer respecting the scientific results of his expedition:—

"I forward to you a copy of the account of my last voyage to New Guinea. I have not given any account of the results of the voyage as regards the collections of natural history, but I now inform you that the collection made is certainly less than I anticipated. Still, considering the great difficulties I had to encounter I ought to be satisfied. I have eight hundred skins of birds, including about two hundred species, of which I hope that twenty or twenty-five will prove to be new to science. Others will be interesting from the localities in which they were to be found and also from their rarity. I procured another specimen of the *Harpyopsis nova guinea*, the fourth obtained by me in New Guinea, and it is certainly remarkable that it has never been obtained by any other traveller in New Guinea. I also found the rare ground-pigeon, *Gymnophaps albertisi*, which I had previously obtained at Dorey in 1872, but it is so rare there that only one or two specimens were found by Beccari and Bruijn, and I have likewise two or three new parrots. Among the insects there are many very beautiful, and no doubt many of them will be new. The examination of my collections will be interesting to naturalists as showing the capricious distribution of animal life; for among my beetles from Papua, there are some found in Australia, and others indigenous to the Philippine Islands. I may also mention that I found a fine Buprestis (*Stigmodera duboulayi*), which is very rare, and known only in Western Australia. I may also have in my collection one or two new mammals, but this will be decided when I bring my collections to Europe."

THE REV. ROBERT MAIN, F.R.S.

PRACTICAL astronomy in this country has sustained a serious loss in the death of the Rev. Robert Main, which took place at the Radcliffe Observatory, Oxford, on the morning of May 7. Mr. Main entered at Queen's College, Cambridge, and graduated as sixth wrangler in 1834, and was Fellow of his college 1836-38, taking clerical orders in 1836. On the appointment of the present Astronomer-Royal he was selected to fill the office of First Assistant in the Royal Observatory, Greenwich, which position he retained, until, on the death of Mr. Johnson, he was appointed, in June, 1860, to the direction of the Radcliffe Observatory. During his connection with the Royal Observatory he was a frequent contributor to the *Memoirs* of the Royal Astronomical Society, his first paper "On the Node and Inclination of the Orbit of Venus" having been presented in June, 1837. This was followed by memoirs "On the Correction of the Mean Distance, Eccentricity, Epoch, and Longitude of the Aphelion of the Orbit of Venus," and he returned to the same subject in two subsequent communications read April 13 and December 14, 1838. In May, 1840, Mr. Main contributed a paper on "The Present State of our Knowledge of the Parallax of the Fixed Stars," which was of much value at the